NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

IMPACT OF DIFFUSION AND VARIABILITY ON VENDOR PERFORMANCE EVALUATION

1 October 2005

by

Kenneth Doerr,
Associate Professor

Ira Lewis,
Associate Professor

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Naval Postgraduate School
Monterey, California

RDML Richard H. Wells   Richard S. Elster
President   Provost

The Acquisition Chair, Graduate School of Business & Public Policy, Naval

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The report was prepared by:

_____
Kenneth Doerr, Associate Professor
Graduate School of Business & Public Policy

_____
Ira Lewis, Associate Professor
Graduate School of Business & Public Policy

Reviewed by:

_____
Robert N. Beck
Dean, Graduate School of Business & Public Policy

Released by:

_____
Leonard A. Ferrari, Ph.D.
Associate Provost and Dean of Research

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Ira Lewis, Associate Professor

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In this paper we develop a theory of the impact of behavioral decision making factors on the evaluation of logistic service providers under performance-based logistics and provide an analysis of pilot data collected in an attempt to find support for that theory. Based on a review of the logistic measurement, PBL, and behavioral decision making literature, we form four hypotheses about specific impacts of process measures and variance on performance evaluation in PBL. Our first hypothesis is that the difficulty of relating component-level measures to system-level outcomes will lead to an increased use of non-diagnostic or only partially diagnostic process measures. We further propose that these process measures will produce a *dilution effect* in which system outcomes are undervalued. Our third hypothesis is that absent clear, observable outcome metrics at the component level, decision makers will increasingly rely on measures of *inputs* as surrogates for outputs. Our fourth hypothesis is that absent a specific guidance on how to value variance, decision makers will tend to overlook this important component of performance. We report results from a pilot test conducted to develop an instrument that will be used to try to find support for hypotheses two and four.

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Abstract

In this paper we develop a theory of the impact of behavioral decision making factors on the evaluation of logistic service providers under performance-based logistics and provide an analysis of pilot data collected in an attempt to find support for that theory. Based on a review of the logistic measurement, PBL, and behavioral decision making literature, we form four hypotheses about specific impacts of process measures and variance on performance evaluation in PBL. Our first hypothesis is that the difficulty of relating component-level measures to system-level outcomes will lead to an increased use of non-diagnostic or only partially diagnostic process measures. We further propose that these process measures will produce a *dilution effect* in which system outcomes are undervalued. Our third hypothesis is that absent clear, observable outcome metrics at the component level, decision makers will increasingly rely on measures of *inputs* as surrogates for outputs. Our fourth hypothesis is that absent a specific guidance on how to value variance, decision makers will tend to overlook this important component of performance. We report results from a pilot test conducted to develop an instrument that will be used to try to find support for hypotheses two and four.

Keywords: Performance-based Logistics, PBL, Behavioral Decision Making, Process and Outcome, Outcome Bias

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About the Authors

Kenneth Doerr, Associate Professor

Naval Postgraduate School

Dr. Ken Doerr, B.S. Indiana University, 1984; Ph.D. University of Washington, 1994. Prior to joining the faculty at the Naval Postgraduate School, he taught at the University of Miami, the University of Washington and Santa Clara University, and also held research fellowships at the University of Waterloo and the University of Cincinnati. He has worked for Shell Oil, Monsanto Corporation and Peoplesoft in manufacturing and supply chain systems. His research has appeared in several leading journals, including *Management Science*, *The Academy of Management Review, IIE Transactions* and *The Journal of Applied Psychology*. His research interests are in work design, and the valuation of technology to facilitate operations. Dr. Doerr is originally from St. Louis, Missouri.

Ken Doerr
Associate Professor
Graduate School of Business & Public Policy
Naval Postgraduate School
555 Dyer Road, GB/Nd
Monterey, CA 93943
Phone: (831) 656-3625
E-mail: khdoerr@nps.edu

Ira Lewis, Associate Professor

Naval Postgraduate School

Ira Lewis is Associate Professor of Logistics and Associate Dean for Faculty Affairs in the Graduate School of Business and Public Policy at NPS. His interests include outsourcing, the impact of information technology on logistics, and transportation.

Ira Lewis
Associate Professor
Graduate School of Business & Public Policy
Naval Postgraduate School
555 Dyer Road, GB/Le
Monterey, CA 93943
Phone: (831) 656-2464
E-mail: ialewis@nps.edu

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Executive Summary

Performance-Based Logistics (PBL) is an initiative that the Department of Defense (DoD) has targeted for 'aggressive implementation' in FY 2006-2009 (Wolfowitz 2004). It is an initiative intended to improve weapon system logistics outcomes, and reduced weapon system lifecycle costs. Provider evaluation in PBL is intended to center on clearly specified outcome metrics, and mutually-agreed upon goals on those metrics (DUSD-LMR 2001) with the idea that the DoD knows best what it wants in terms of logistic services, but the vendor may know best how to provide those services. PBL can be seen as an extension of the principle of "commander's intent" in which leadership presents goals, but subordinates are encouraged to choose methods and processes (Apgar IV and Keane 2004).

Within the field of behavioral decision making, there is a substantial literature which shows that decision makers use sub-optimal heuristics to value and negotiate agreements such as PBL contracts for services, and are subject to systematic biases in judgment when evaluating performance (Kahneman, Slovic et al. 1982). In this paper, we draw a connection between the intent of PBL on the one hand, and the literature on biases and heuristics on the other. Specifically, we review the literature on PBL and logistics service measurement as it relates to 1) the distinction between process and outcome measures and 2) the significance of risk. We then review the literature on behavioral decision making and performance evaluation that relates to those same two topics, and develop hypotheses regarding 1) the potential impact of process measurement on outcome measurement, and 2) the absence of stated metrics and goals for the variance (risk) of outcomes. We develop specific, testable hypotheses from this review of the literature, report on a test of these hypotheses in a laboratory experiment, and discuss the implications of our findings on practice.

PBL is an evolving concept within the DoD, and clarification on the metrics which should be used to assess weapon system logistics outcomes has been recently issued which emphasizes that system-level outcomes such as operational availability should be used to evaluate PBL candidates and the performance of PBL providers (Wynne

2004). The system-level emphasis of this clarification is significant and proper, as warfighting outcomes are clearly only impacted by system level (as opposed to component level) performance.

But PBL is still being applied at the component level and there is no clear guidance (to our knowledge) on how to link component level variables like time-to-failure to system level outcomes like operational availability. Indeed, a recent Government Accountability Office (GAO) report found that most of the 185 PBL contracts they were able to identify in the DoD were written at the component or subsystem level, and they suggested that contracting at the component level should continue to be preferred to contracting at the system level (GAO 2004).

Even in the private sector, the measurement and performance assessment of logistic services is known to be a difficult task. Proper valuation of the outcomes of logistic services (as opposed to merely valuing inputs, such as cost) must include some assessment of difficult to quantify factors such as customer satisfaction, and risk reduction (Lambert and Burduroglu 2000). This outcome measurement problem is made more difficult because so many of the traditional logistics measures are process measures (Caplice and Sheffi 1994). Nor is it easier when the services are provided to the DoD, where outcomes cannot be reduced to measurable quantities like profit or shareholder value (Camm, Blickstein et al. 2004).

The DoD of course has no simple overarching valuation metric such as profit, and it has no simple revenue surrogates. Valued outcomes have to do with military missions; thus, even if logistic services for a weapon system are provided at an aggregate level by a single provider, they are difficult to value and price. At the level of a subassembly or single logistic element, the problem is compounded. Unless decision makers have comprehensive models of weapon systems logistics, in which the important performance dimensions of all critical components are modeled, they cannot value a component-level contract in terms of system level outcomes like operational availability. Such models have not been required, and we have no evidence that they are being used in the field.

In situations without clearly observable outcome measures and valuation functions, decision makers are known to place a heavy weight on surrogates such as process measures, or even input measures (Chinander and Schweitzer 2003). Some of these may not correlate well with system-level outcomes. Under PBL, decision makers must determine relevant outcomes for component level contracts and separate diagnostic measures (those that correlate well with desired system outcomes) from non-diagnostic ones. However, decision makers are known to pursue information even when it is non-diagnostic and non-instrumental (knowledge of the measure would not or should not change decisions). Unfortunately, once obtained, such non-instrumental information may be treated as if it were instrumental (Bastardi and Shafir 1998). That is, decision makers pursue information they do not need, then act upon it. In our paper, we investigate this tendency in decision makers asked to evaluate provider performance under a hypothetical PBL contract.

It might be claimed that additional information could never hurt the decision process (aside perhaps from the cost of gathering it) but at least two sets of research findings indicate that such confidence would be misplaced. The curse of knowledge is a dysfunctional decision making pattern that occurs when a decision maker knows information that they would be better off to ignore, but they cannot ignore it (Camerer, Loewenstein et al. 1989). The classic example is a wine merchant, who over prices his good wine, and under prices his bad wine and thus loses revenue on both sides from customers who do not know as much about wine as he does. In our case, the decision maker who pursues non-diagnostic process information may misestimate provider performance because of it. A related bias is the dilution effect: the tendency for non-diagnostic information to cause diagnostic information to be undervalued (Nisbett, Zukier et al. 1981). In the case of PBL, if a decision maker captures process metrics, he or she may not be able to place them in the proper context relative to a system level outcome, and the impact of an important outcome metric may be diluted. In our paper, we investigate the tendency of decision makers to dilute system outcomes when given knowledge of process variables.

A special case of the misuse of non-diagnostic information is the use of information about inputs. The input bias is the tendency to make judgments about the quality of outcomes based on the value of inputs (Chinander and Schweitzer 2003). For example, people tend to judge the quality of a product or service higher when they have to wait longer for it (Maister 1985). This bias is thought to play an especially significant role in evaluation when outcomes are difficult to observe or measure. In the case of PBL contracts, the evaluation of proposals based solely on the relative cost of alternatives would be an example of an input bias. Also, a performance evaluation that considered investments a provider made in achieving outcomes would be an example of an input bias. In our paper, we investigate the susceptibility of decision makers to an input bias when evaluating the performance of logistic service providers.

There are other reasons why decision makers may seek out component-level process measures, even when they have been directed to look at system level outcome measures. Process measures allow a better degree of control over the internal workings of a process. They may not reduce uncertainty around outcomes, but they do give decision makers a sense that outcomes are more directly under their control. Risk preferences vary widely, but in addition to individual differences in risk aversion or risk seeking behavior, decision makers tend to prefer controllable to uncontrollable ones even to the extent that they will maintain illusions about the degree of control they have over a situation (Langer 1975). The preference for controllable risks is said in part to be related to a general bias decision makers have that their own abilities are better than others (Howell 1971). Of course, part of the logic of performance-based outsourcing is that providers are more capable of dealing with the internal processes of the logistics service. But decision makers appear to maintain this preference for controllable risks, and to support their bias toward exaggerated self-assessments, even when they would be better off with less control (Klein and Kunda 1994).

In delegating the decisions on how to accomplish outcome goals to a provider, programs seek to use PBL to transfer some of the process and financial risk of the logistic service to the provider; in contracting to deliver outcomes while assuming responsibility for processes, providers accept that risk at a specified price. The

assessment of these risks is part of a business case analysis required for every implementation of PBL in the Navy (Young 2003).   To our knowledge however, DoD-level PBL guidance does not require any specific measures of outcome risk, or process risk transfer.

The biases and heuristics literature makes it clear that human decision makers are poor intuitive statisticians (Kahneman, Slovic et al. 1982). However, as Cohen (1982) pointed out, if decision makers could intuitively grasp statistical concepts, what would be the point of offering classes in them? Whether it is a question of education or irrationality, it seems clear that most decision makers do not have an intuitive model that allows them to value variance in, for example, operational availability. In our paper, we investigate the tendency for decision makers, even when trained in risk assessment, to undervalue the impact of outcome variance.

The investigations in our paper are all made through laboratory experiments: questionnaires asking decision makers to evaluate PBL scenarios. The results have only limited generalizability to the actual management of extant PBL contracts, or to the valuation and pricing of PBL contracts. However, the results do have implications for the continued evolution of PBL, and the need for greater specificity in guidance. That is, if decision makers under PBL are subject to the same limitations as decision makers in our study, it indicates the need for the DoD to develop specific guidance with regard to risk measurement and valuation, and to require comprehensive system-level models to value and price component level contracts, and evaluate component level logistic service provider performance.

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Introduction

Performance-Based Logistics (PBL) is an initiative that the Department of Defense (DoD) has targeted for "aggressive implementation" in FY 2006-2009 (Wolfowitz, 2004). It is an initiative intended to improve weapon system logistics outcomes, and reduce weapon system lifecycle costs. Important weapon system logistics outcomes have been defined (each of the following will be explained in more detail below) as operational availability, operational reliability, cost per usage, logistics footprint, and logistics response time (Wynne, 2004).

PBL is different from traditional military logistics management in that program managers are supposed to dictate what a logistics service provider should deliver in terms of measurable outcomes, not how the delivery of those outcomes should be accomplished. It can be seen as an extension of the principle of "commander's intent" in which leadership presents goals, but subordinates are encouraged to choose methods and processes (Apgar & Keane, 2004). Whether the service provider is an organic DoD organization or a private sector organization, it must enter into a contractual relationship with weapon system managers in which payment is based on performance relative to agreed-upon outcome goals.

In delegating the decisions on how to accomplish outcome goals to a vendor, programs seek to use PBL to transfer some of the operational and financial risk of the methods and processes used to the vendor; and in contracting to deliver outcomes while assuming responsibility for processes, vendors accept that risk at a specified price. The assessment of these risks is part of a business case analysis required for every implementation of PBL in the Navy (Young, 2003).

The measurement and performance assessment of logistic services is clearly a difficult task. Cost reduction is not an adequate assessment of the strategic benefits of logistic services, which must include some assessment of difficult-to-quantify factors such as customer satisfaction and risk reduction (Lambert & Burduroglu, 2000). This measurement problem is not made easier when an organization focuses on outcomes

to be acquired—rather than processes to be monitored—because so many of the traditional logistics measures are process measures (Caplice & Sheffi, 1994). Nor is it easier when the services are provided to the DoD, where outcomes cannot be valued in terms of profit or shareholder value (Camm, Blickstein et al., 2004).

Indeed, it is one of the premises of this paper that because logistics is so often considered an internal process (or even a sub-process) of an activity, outcomes are difficult to value. This is especially true for weapon systems logistics, in which even what are usually considered outcome measures (e.g., operational availability) have no one-to-one correspondence to recognizable outcomes valued by the DoD (e.g., mission success). Without clearly observable (let alone valuable) outcome measures, decision makers are known to place a heavy weight on surrogates such as process measures, or even input measures (Chinander & Schweitzer, 2003). We will investigate the potential for bias in performance evaluation created by the attempt to measure and value system-level outcomes, when the services contracted are only sub-processes of weapon system operations and support.

Another premise of this paper is that the risk transfer intended by delegating processes must be assessed through the measurement of outcome variance. After all, risk, in Finance or Logistics, is synonymous with variance. In allowing a vendor to choose methods and processes, a manager must hold him or her accountable for the *reliable* delivery of outcomes. One DoD organization, in issuing guidance for vendor management under PBL, stated the following:

> Minimal contract management involvement is anticipated as long as the contractor meets contractually specified performance metrics. However, our involvement may increase if the contractor systems and processes are not functioning correctly and end users are not appropriately supported. (Bogusz, Taylor et al., 2002)

In our opinion, true risk transfer has not taken place if "involvement may increase" when contractor processes are not functioning correctly. If the vendor is not responsible for correcting the variance in their processes, then the DoD is still in the

business of managing processes, not outcomes, and should continue to measure processes as well as outcomes (and should not be paying someone else for the management of the process). This is not to say that a manager should simply ignore the potential impact of process variance. But consequential process variance will show up in outcome variance as well, and outcome variance is itself an important performance dimension.

For example, if a vendor has contracted to provide a certain level of operational availability for a component, one of the sub-processes that will determine operational availability is maintenance lead time. Problems (variance) in the sub-process of maintenance lead time will create variance in operational availability. That is, one does not need to monitor a sub-process to observe the impact of the variance of that sub-process: it can be observed through variance in system-level outcomes. Of course, variance in operational availability is itself an important performance dimension, as it determines the risk that the number of mission-capable assets will fall below some planning threshold. But in addition to determining direct performance implications of outcome variance, by monitoring outcome variance, the DoD implicitly monitors variance (risk) in all of the sub-processes that determine that outcome. Risk can be said to have been *successfully* transferred only when operational (or financial) risk has been reduced.

In the next section, we will review the literature on PBL and logistics service measurement as it relates to: 1) the distinction between process and outcome measures and 2) the significance of risk. We will then review the literature on behavioral decision making and performance evaluation that relates to those same two topics, and develop hypotheses regarding: 1) the potential impact of process measurement *on* outcome measurement and 2) the absence of stated metrics and goals for the variance of outcomes. We will develop specific, testable hypotheses from this review of the literature. Next, we will report on preliminary findings relating to the development of an instrument to test two of our hypotheses. Finally, we will discuss the implications of our hypotheses and managerial implications, should support for them be found in later work.

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PBL, Logistics Measurement and Behavioral Decision-Making Research

The key word in Performance-Based Logistics is "performance," which means "specification and valuation of outcome *rather than* process." There are a number of other related US Government and DoD initiatives which use the word performance in this way—for example, Performance-Based Service Contracting (OFPP, 1998) and Performance-Based Service Acquisition (DUSD-DAR, 2000). The use of the term performance in all of these initiatives is at least in part intended to imply a break from the past, which is seen as involving needlessly complex specification and micro-management of vendor processes, when vendors sometimes understand the methods of service delivery better than the governmental customer who is buying the service. Vendor evaluation in "performance" initiatives is intended to center on clearly specified outcome metrics and mutually-agreed upon goals on those metrics (DUSD-LMR, 2001), with the idea that the DoD knows best what it wants in terms of logistic services, but the vendor may know best how to provide those services.

Logistic services present a problem in this regard, however, because many aspects of performance—especially those relating to the benefits (and not the costs) of the service—deal with difficult-to-measure factors such as customer perception of service quality (Mentzer, Flint et al., 1999) or customer value added (Lambert & Burduroglu, 2000). Also, the vast majority of logistic services measures involve what have been called "utilization" measures (ratios of actual to normalized inputs) or "productivity" measures (ratios of actual output to actual input) on single resources—in other words, sub-processes within the logistic service, such as items picked/man-hour in a warehouse. Few total factor "effectiveness" measures (ratios of outcomes to normalized outcomes, or goals) are used (Caplice & Sheffi, 1994). But these are precisely the sorts of measures prescribed under PBL.

Weapon system logistics may be even more difficult to assess in terms of outcomes because the relationship between support services and mission outcomes valued by the DoD is even more attenuated than the relationship between support

services and profit in the commercial sector (Doerr, Lewis et al., in press). Finally, PBL has been implemented for individual logistic elements (e.g., inventory alone or repair alone) at the component or sub-assembly level of weapons systems. The relationship between logistic support services at the component or individual logistic-element level, and outcomes at the weapon-system level is difficult to determine and probabilistic in nature, as it depends on the performance of the other critical components and logistical elements that determine overall system performance.

In the past, measures have been recommended for PBL contracts that are clearly process, and not outcome measures. For example, Fill Rate or back-order aging rates have been suggested (Bogusz, Taylor et al., 2002). When measured at a component level (e.g., fill rate for a fuel cell), the connection of these measurements to system-level outcomes is so tenuous as to be impossible to determine in isolation from the process metrics of other major components (Kang, Doerr et al., 2005). In recent high-level guidance for PBL, the DoD has made it clear that system-level performance (outcome) metrics should be negotiated with a PBL vendor. A recent memo from the Deputy Undersecretary of Defense for Acquisition, Technology and Logistics (Wynne, 2004) listed five key performance criteria: 1) weapon *system* operational availability, 2) weapon *system* operational reliability, 3) weapon *system* cost per usage, 4) logistics footprint for a weapon *system,* and 5) response time required for weapon *system* logistics support. However, even in this reduced subset of important variables, aspects of reliability (time to failure for a component) and logistics footprint (spares inventory levels in the field) can be seen as process variables which help to determine the "outcome" of operational availability.

Moreover, PBL is still being applied at the subsystem, or major assembly level, and there is no clear guidance on how to link component-level variables like time-to-failure to system-level outcomes like operational availability. Indeed, a recent GAO report found that most of the 185 PBL contracts they were able to identify in the DoD were written at the component or subsystem level, and they suggested that contracting at that level should be preferred to contracting at the platform, or system level (GAO, 2004). This GAO recommendation seems, in large part, to have been justified on the

basis of commercial practices; nowhere does it address the significant difference between DoD and private-sector logistics in terms of relating component-level variables such as component reliability or availability to system-level outcomes. In the private sector, the central financial valuation question in such a contract (i.e., the question of how to price it—apart from any strategic consideration) would revolve around the cost and *revenue* implications: if the rate of return of the contract was predicted to exceed a corporate hurdle rate for *profitability*, it would likely be adopted (depending, in addition on the strategic considerations).

The DoD, of course, has no simple valuation metric such as profit, and it has no simple revenue surrogates. Valued outcomes have to do with military missions, and the driving surrogate for those (from the logistics point of view) is readiness. And while readiness as a surrogate may be seen to beg the question of valuation (e.g., how ready for what mission contingency?), its common operationalization as Ao (operational availability) is even more distal. Thus, even if logistic services for a weapon system are provided at an aggregate level by a single provider, they are difficult to value and price. At the level of a subassembly or single logistic element, the problem is compounded. Reducing mean time to repair for an auxiliary power unit (APU), for example, may increase the probability that a spare APU will be on the shelf if needed (though even that relationship is not trivial to derive); but, the impact of this higher probability on Ao of an aircraft depends on the sparing level, failure rates, and time to repair of all the other critical components of the aircraft. Unless decision makers have comprehensive models of weapons systems logistics, in which the important performance dimensions of all critical components are modeled, they cannot value a component-level contract in terms of system-level outcome surrogates like Ao. Such models have not been required, and we have no evidence that they are being used in the field.

So, if component-level contracts are not being valued in terms of system-level outcomes, how are new contracts being valued and priced? And how is performance on ongoing component-level contracts being evaluated? This, of course, is an empirical question, and we have no field evidence to address this question one way or the other. However, we can draw on a substantial literature in the domain of behavioral decision

making to build hypotheses about how decision makers typically value and evaluate performance when outcomes are difficult to observe or measure.

There is a substantial literature to suggest that decision makers (even in unambiguous situations) use sub-optimal heuristics to solve problems and are subject to biases in judgment (Kahneman, Slovic et al., 1982). In PBL, we think measurement and valuation difficulties will promote certain biases and cause decision makers to overlook important aspects of valuation (risk). These difficulties include the distal relationship between component-level processes and system-level outcomes, and the difficulty of proper valuation of variance in outcome measures.

There has been research which suggests that performance-based evaluation may itself create judgmental bias. The *outcome bias* is the tendency to assume that outcomes and processes are more strongly related than they really are—that correct process decisions lead to desired outcomes, even when they do not (Baron & Hershey, 1988). Because good decisions may sometimes lead to bad outcomes (and vice-versa), some degree of evaluation based on processes themselves seems normatively preferable. There has been some debate about whether judgment based solely on outcome might be justified at all (Hershey & Baron, 1992; Lipshitz, 1995); yet, a situation in which the decision maker knows relatively little about the processes used to obtain the outcome has been said to be indicative of a case where judgment by outcome might be preferred.

Even taking the premise of judgment-by-outcome as given for PBL, there remains the problem of determining relevant outcomes for component-level contracts and separating *diagnostic* measures (those that correlate well with desired system outcomes) from non-diagnostic ones. Although guidance has been given as to the nature of system-level outcome measures that should be included in PBL contracts (Wynne, 2004), there has been no clear guidance (to our knowledge) on how to relate sub-system processes and outcomes to system outcomes, and no strict guidance that managers should limit evaluation to those metrics that relate to system-level outcomes. In situations with uncertainty, decision makers are known to pursue information even when it is non-diagnostic and non-instrumental (knowledge of the measure would not or

should not change decisions). Unfortunately, once obtained, such non-instrumental information may be treated as if it were instrumental (Bastardi & Shafir, 1998). That is, decision makers pursue information they do not need, then act upon it.

Logistic services, as already noted, are difficult to measure, and a large number of process metrics have been used for various logistics elements (Caplice & Sheffi, 1994). When applied at a component level, many of these metrics will correlate at least to some degree with system-level outcomes such as operational availability (though some will not). But the precise nature of the relationship between a logistics measure such as warehouse turnover for a certain type of tire, and operational availability of a jet is quite difficult to determine. Given the abundance of such measures, however, and the difficulty of the task of measuring system outcomes, we think it is likely that decision makers will pursue such non-diagnostic, or partially diagnostic information about the logistic processes of components under PBL contracts.

Hypothesis 1: In evaluating vendor performance for outsourced logistics services, decision makers will seek out process measures that only partially correlate with system-level outcomes, even when they are given system outcome measurements.

This would not necessarily be a problem (indeed, according to the tenets of the outcome bias, it might be beneficial) were it not for the very quantity of process measures available, and the difficulty of discerning those that might be the most instrumental from those likely to be the least. It might be claimed that additional information could never hurt the decision process (aside perhaps from the cost of gathering it), but at least two sets of research findings indicate that such confidence would be misplaced.

The *curse of knowledge* is a dysfunctional decision-making pattern that occurs when decision makers know information they would be better off to ignore, but once they know it, they cannot ignore it (Camerer, Loewenstein et al., 1989). The classic example is a wine merchant who over-prices his good wine and under-prices his bad wine because he "knows" about his wine. He, thus, loses revenue on both sides from customers who do not know as much about wine as he does. In our case, the decision

maker who pursues non-diagnostic process information may tend to overvalue vendor performance (if the non-diagnostic numbers were better than the system outcome metrics) or undervalue it (if the non-diagnostic numbers were worse than the system outcome metrics).

Another related bias is the *dilution effect:* the tendency for large quantities of non-diagnostic information to cause diagnostic information to be undervalued (Nisbett, Zukier et al., 1981). In the case of PBL, if a decision maker captures large numbers of logistic process metrics, the impact of an important outcome metric may be overlooked.

Hypothesis 2: Decision makers given non-diagnostic or partially diagnostic information about component-level processes will use it to moderate their evaluations of system-level outcomes.

A special case of the misuse of non-diagnostic information is the use of information about inputs. The *input bias* is the tendency to make judgments about the quality of outcomes based on the value of inputs (Chinander & Schweitzer, 2003). For example, people tend to judge the quality of a product or service higher when they have to wait longer for it (Maister, 1985). This bias is thought to play an especially significant role in evaluation when outcomes are difficult to observe or measure. In the case of PBL contracts, the evaluation of proposals based solely on the relative cost of alternatives would be an example of an input bias. Also, a performance evaluation that considered investments a vendor made in achieving outcomes would be an example of an input bias.

Hypothesis 3: Decision makers will use input information such as cost or effort expended on component-level processes to moderate their judgments of system-level outcomes.

There are other reasons why decision makers may seek out component-level process measures, even when they have been directed to use system-level outcome measures. Process measures allow a better degree of control over the internal workings of a process. They may not reduce uncertainty around outcomes, but they do

give decision makers a sense that outcomes are more directly under their control. Under PBL, decision makers are supposed to avoid the temptation to exercise process control, and specify and evaluate contractors based solely on outcomes. However, this intention seems hard to realize. When we first presented data we had gathered that indicated some stakeholders in the PBL process felt it entailed "too many metrics," a DoD decision maker raised the objection that the number of metrics was irrelevant, and pointed out that pilots have a superabundance of indicators in their cockpits, most of which they ignore unless something is going wrong. But of course, under performance-based contracting, one isn't supposed to be flying the plane: one is supposed to be buying a ticket to ride as a passenger.

Risk preferences vary widely, but in addition to individual differences in risk-aversion or risk-seeking behavior, decision makers tend to prefer controllable to uncontrollable risk even to the extent that they will maintain illusions about the degree of control they have over a situation (Langer, 1975). The preference for controllable risks is said, in part, to be related to a general bias decision makers have that their own abilities are better than others' (Howell, 1971). Of course, part of the logic of performance-based outsourcing is that vendors are more capable of dealing with the internal processes of the service. But decision makers appear to maintain a preference for controllable risks, and to support their bias toward exaggerated self-assessments, even when they would be better off with less control (Klein & Kunda, 1994).

Finally, as already noted, we think the variance (risk) associated with outcomes is itself an important performance measure that should be explicitly considered in valuing and evaluating outsourced logistic services. This is both because (process) risk transfer *is* an intended outcome of PBL (and, hence, it should be measured to see if that outcome is obtained), but also because variance in outcomes directly affects contingency planning for operations. Unfortunately, while PBL guidance clearly indicates the importance of risk (Young, 2003), that guidance does not require specific measures of risk. The biases and heuristics literature makes it clear that human decision makers are poor intuitive statisticians (Kahneman, Slovic et al., 1982). Indeed, one of the early criticisms of the research on biases and heuristics is that in part, it

merely represents a set of tests of intelligence or educational achievement (Cohen, 1982): if decision makers could intuitively grasp statistical concepts, what would be the point of offering classes in them? It would be beyond the scope of this paper to document the many intuitive heuristics decision makers use to deal with uncertainty and risk. Whether it is a question of education or irrationality, however, it seems clear that most decision makers do not have an intuitive model that would allow them to value variance in, for example, operational availability.

Hypothesis 4: Decision Makers will undervalue or ignore information about outcome variance, unless it is made salient to them, along with a method for its proper valuation.

Scale Development and Results of a Pilot Experiment

In this section we describe both the results of a scale development effort to measure vendor performance and pilot results from data collected to help validate the scale. Findings are also given from these pilot data that relate to two of our hypotheses.

Participants.

Participants were 63 professional military officers enrolled in an MBA program at a public university. The average participant age was 33.6 years with an average of 11.7 years of active duty service; 86.7 percent of the participants were male. Participants had an average of 4.3 years of experience in logistics and 1.3 years of experience in contract management. 66.7 percent of the participants indicated prior knowledge of PBL.

Protocol.

Participants were given a short description of a scenario in which the depot-level support of a weapon system component was outsourced to a vendor. Participants were told that the component, weapon system and vendor were fictitious. They were told that their responses were to be used to assess biases based on variance in decision scenarios. Each participant was given one of three scenarios, as described below. No extra credit was given for participation in the study, and participants were assured both of the confidentiality of their responses and the voluntary nature of their participation.

Instrument.

All participants were given the same two-page scenario description. The description stated that the primary weapon system outcome of concern was Operational Availability. The description also pointed out that the component which had been outsourced to the vendor was only 1 component of many which determined operational availability for the weapon system; and depot-level maintenance of that component was only one logistical element of many which determined the performance of that component in the aircraft. See Figure 1.

Figure 1. Graphic Given to Participants to Support Description of Depot-Level Repair within System-Level (Aircraft) Availability
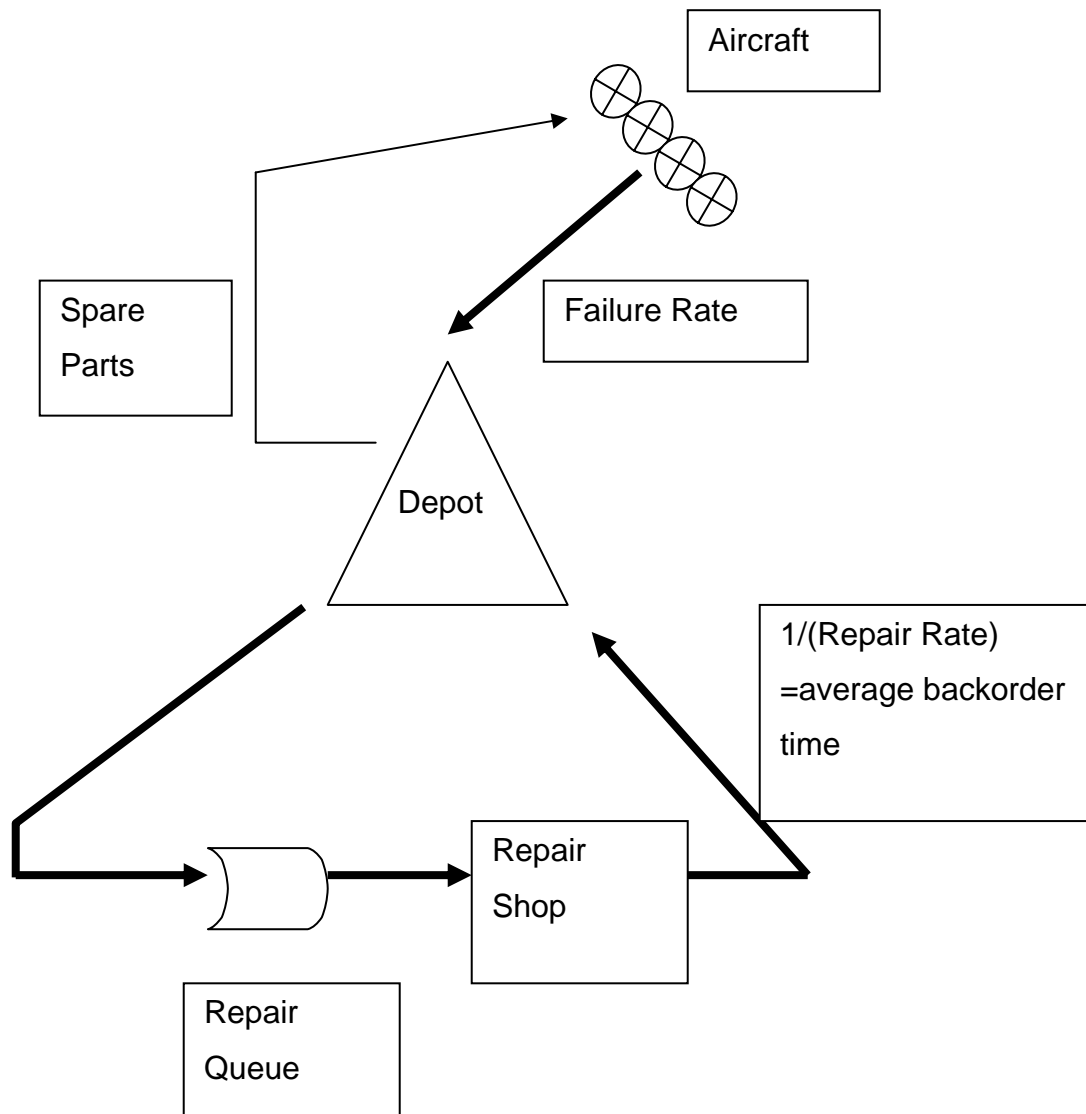
The three forms of the instrument differed in the data that was presented to the participants. In the base case, participants were given only data on how many weapon systems (aircraft) were down due to failure of the component. As aircraft availability was stated to be the outcome of concern, the data provided was a good outcome surrogate. Weekly data were provided from a two-year period (prior year and contract year), and the average number of aircraft down due to BQV failure was shown to have

increased slightly during the contract year from the prior year (i.e., performance worsened).

In the second form of the instrument, in addition to the outcome information, participants were also given data from process measures which only partially correlated with the outcome of concern. In particular, participants were given weekly data from a two-year period (prior year and contract year) on the average mean time between failures for engines in a given week, average repair cycle time, and average days to supply backorders. In each case, the impact on system performance cannot be determined directly from the numbers. However, in each case, performance on these process measures improved slightly from the prior year to the contract year.

In the third form of the instrument, participants were not given the process measures, but attention was drawn to the variability of the outcome (number of aircraft down due to component failure). The only additional piece of information given to the participants on the third form was the standard deviation of the outcome for each year. Variance in the contract year had been reduced by a factor of four compared to the prior year, from 14.3% standard deviation in aircraft availability to 6.0% standard deviation in aircraft availability. In other words, while average performance was very slightly worse in the contract year compared to the prior year, performance was far more reliable in the contract year. In the base case, the participants were given weekly data from 2 years (52 x 2 numbers), but the standard deviation was not given. The participants in the base case could have calculated the number themselves, or simply observed the large decrease in variability by carefully checking the data; however, they were not directed to do so. On the third form of the instrument, the standard deviation of outcomes was given in order to draw attention to the reduction in variability.

Every participant answered the same seven questions. There were 6 items in the survey intended to provide a global assessment of vendor performance (this was the scale being piloted) and a seventh item asking participants to set a performance award for the vendor (0-5 percent of cost bonus). The seventh item was intended to provide a check of convergent validity for the first six items. The six items in the vendor performance scale are given in the Appendix.

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Analyses.

Cronbach's alpha was used to assess internal reliability of the six-item scale. Independent sample t-tests were used to assess differences between participants' responses when given one of the two "treatment" forms (containing additional data) and participants' responses when given the base-case form. Congruence between outcome variables (six-item scale or percentage award) was assessed qualitatively by examining descriptive statistics and the outcome of t-tests run using each of the outcome variables.

Results.

Descriptive statistics (mean and standard deviation) for each of the two dependent variables are given in Table 1 for all three participant groups.

Table 1. Pilot Results (Mean, Standard Deviation)

Group	Outcome Only (base case)	Process Measures Given	Std. Dev. Given
6-Item Performance Scale	14.3, 3.7	17.4, 4.4	16.6, 3.8
Percent Award	0.8, 1.2	0.5, 0.8	1.5, 1.2

The six-item vendor performance scale exhibited reasonable internal reliability on this sample ($\alpha = .791$, N = 61).

Independent sample t-tests showed mixed support for Hypothesis 2. Although participants' performance evaluation increased when given data on process measures (t = 2.116, p = .022), their percentage award to the vendor did not increase (t = -0.854, p = .20). The failure to find the predicted result for the percentage award result may be partially be due to a combination of high variance (the coefficient of variation is greater than one for both groups, and the t-test is not significant) and a truncation effect (a large number of participants gave zero award in both groups).

Independent sample t-tests showed strong support for Hypothesis 4. On both the performance evaluation scale (t = 1.782, p = .043) and the percentage award (t = 1.586, p = .062), evaluations were significantly higher when the difference in variance was made plain by printing the standard deviation with the data.

The results show, at best, mixed support for the convergent validity of the performance-evaluation scale and percentage-bonus awards. This may be due to technical issues with the percentage-award scale (noted above) or it may be that participants viewed performance evaluation (as measured by the six-item scale) as different in substance from performance awards.

Limitations, Discussion and Conclusion

The primary purpose of the pilot data collection was to validate a scale for use in further testing; however, since we have reported results from this pilot experiment, we should also make clear a number of limitations to interpreting the results. First, a number of controls and manipulation checks were omitted in the pilot experiment. For example, while we tried to make it clear that system availability was the important weapon system outcome to be assessed in the pilot, we did not perform a manipulation check to make sure that participants understood this. Also, while demographic data were gathered, no attempt was made on these pilot data to ascertain if these variables explained a significant amount of variance in the dependent variables. Future work, for example, should treat experience with contracting and logistics as a control variable. Finally, while we have been able to report preliminary support for two of our hypotheses, the other two hypotheses could not be tested with the pilot instrument.

In our review of the literature, we have drawn a connection between the intent of performance-based service contracting and PBL on the one hand, and the literature on biases and heuristics on the other. We have shown that the core intentions of performance-based contracting—evaluating performance based on outcomes rather than processes—is itself held in question by decision-making researchers.

We have seen from a review of the logistics measurement literature that logistic services themselves are hard to value and evaluate, in part because outcomes are difficult to quantify. In such a circumstance, behavioral decision research suggests that decision makers will use outcome surrogates, including inputs, to value outcomes. If these strategies are also used in PBL services, their usage would indicate a greater need for guidance in the outcome measures that should be used for PBL contract management.

Much of the earlier guidance on PBL insisted upon the idea that there was not "one best way" to implement PBL, and that measurement, consequently, would also need to vary from contract to contract. While more specific guidance has been given in

the last year clarifying that the important performance outcomes under PBL are at the system level, to our knowledge little specific guidance has been given on the precise mechanisms to be used to connect component-level performance with system-level outcomes. Under such ambiguity, we have seen that behavioral decision making researchers predict that decision makers will seek out and use process measures that are non-diagnostic (not relevant to the evaluation task) or only partially diagnostic of outcomes. Our pilot data provided mixed and limited support for the idea that decision makers will use process measures, even when told that outcomes are more valued, and even when given clear outcome measures. Whether decision makers will actually seek out such process data (Hypothesis 1) remains untested.

Finally, in reviewing the literature on PBL, we have noted that one of the primary intentions of the initiative is to outsource process risk. We have noted that process risk connects to outcome performance through outcome variance, and that it is possible to evaluate the success of process risk transfer without measuring processes directly, but merely through a direct evaluation of outcome variance. However, we have also noted that one of the core lessons of the behavioral decision making literature is that managers are especially poor intuitive statisticians, rely heavily on heuristics such as representativeness to assess probability, and are subject to the influence of a number of biases (such as base rate neglect). Our pilot data have provided limited support for the idea that decision makers will simply neglect variance information unless it is made salient. If decision makers under PBL are subject to the same limitations—if further support is found for our Hypothesis 4—that data indicates the need for the DoD to develop specific guidance with regard to risk measurement and valuation under PBL.

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Appendix 1. Component Logistic Service Vendor Performance Scale

(Note: the BQV is a fictitious component in the H-80, a fictitious aircraft. The contract year reviewed was 2003. All items were measured on a five-point scale, in which one was "strongly disagree," three was "neutral," and five was "strongly agree.")

1. Logistical support of the BQV for the H-80 was good in 2003.
2. The vendor improved logistical support outcomes of the BQV in 2003 to above performance in 2002.
3. The BQV vendor provided better response in support of the H-80 in 2003 than in 2002.
4. The vendor improved performance outcomes of the BQV in 2003 to above performance in 2002.
5. The vendor improved service levels in 2003 to above service levels in 2002.
6. Squadrons were less likely to be short a BQV for an H-80 in 2003 than they were in 2002.

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